A New Approach of Medical Image Fusion using Discrete Wavelet Transform

Maruturi Haribabu[1], CH.Hima Bindu[2], Dr.K.Satya Prasad[3]

[1]Asst.Professor, ECE Department, QIS College of Engineering & Technology, Ongole, India.
haribabu.maruturi@gmail.com
[2]Assoc.Professor, ECE department, QIS College of Engineering and Technology, Ongole, India.
hb.muvvala@gmail.com
[3]Professor in ECE Department, JNTUK, Kakinada, Andhra Pradesh, India.
Prasad_kodati@yahoo.co.in

Abstract— **MRI-PET medical image fusion has important clinical significance. Medical image fusion is the important step after registration, which is an integrative display method of two images. The PET image shows the brain function with a low spatial resolution, MRI image shows the brain tissue anatomy and contains no functional information. Hence, a perfect fused image should contains both functional information and more spatial characteristics with no spatial & color distortion. The DWT coefficients of MRI-PET intensity values are fused based on the even degree method and cross correlation method The performance of proposed image fusion scheme is evaluated with PSNR and RMSE and its also compared with the existing techniques.**

Index Terms— **Image fusion, Discrete wavelet transform, Even degree method, Cross correlation process.**

I. INTRODUCTION

In computer vision, Multisensor Image fusion is the process of combining relevant information from two or more images into a single image. The resulting image will be more informative than either of the input images. Image fusion has become important process in medical diagnostics and treatment. Fused images may be created by combining information from multiple modalities, such as Magnetic Resonance Image (MRI), Computed Tomography (CT), Positron Emission Tomography (PET) and Single Photon Emission computed Tomography (SPECT). For example, CT images are used more often to ascertain differences in tissue density while MRI images are typically used to diagnose brain tumors [1, 2, 4].

Medical image fusion is to collect the information of multi-modality image together, to express information got from multi-modal images in one image at the same time to highlight their respective advantages, to carry out complimentary information and to provide comprehensive morphology and functional information which reflects physiological and pathological changes. Multi-source medical image fusion methods are mainly divided in to three categories: pixel-level based image fusion, feature-level based image fusion and decision-making based image fusion.

In pixel level fusion, the input images are fused pixel by pixel followed by the information extraction. In feature level fusion, the information is extracted from each input image separately and then fused based on features from input images.

In decision level fusion, the information is extracted from each input image separately and then decisions are made for each input channel [3-6].

The organization of this paper is as follows, the section II explains Discrete Wavelet Transform. In section III the methodology for proposed method and the implementation is explained. Finally in section IV the experimental results are shown.

II. DISCRETE WAVELET TRANSFORM

A Discrete wavelet transform (DWT) is any wavelet transform for which the wavelets are discretely sampled. As with other wavelet transforms, a key advantage it has over Fourier transforms is temporal resolution that is it captures both frequency and location information.

Wavelets are finite duration oscillatory functions with zero average value. The irregularity and good localization properties make them better basis for analysis of signals with discontinuities. Wavelet decomposition is widely used in time series and image analysis. Its salient advantage over other analysis methods, especially Fourier transform, is that it can give not only frequency information of a signal, but can also localize that information in the temporal (spatial) domain. Because of their suitability for analysing non-stationary signals, they have become a powerful alternative to Fourier methods in many medical applications, where such signals abound. The main advantages of wavelets is that they have a varying window size, being wide for slow frequencies and narrow for the fast ones, thus leading to an optimal time-frequency resolution in all the frequency ranges [7].

In a 2-D DWT, a 1-D DWT is first performed on the rows and then columns of the data by separately filtering and down sampling. This result in one set of approximation coefficients I_a and three set of detail coefficients, as shown in Figure 1, where I_b, I_c, I_d represent the horizontal, vertical and dialog directions of the image I, respectively. In the language of filter theory, these four sub images correspond to the outputs of low-low (I_a), low-high (I_b), high-low (I_c), and high- high (I_d) bands. By recursively applying the same scheme to the LL sub band a multiresolution decomposition with a desire level can then be achieved [8].
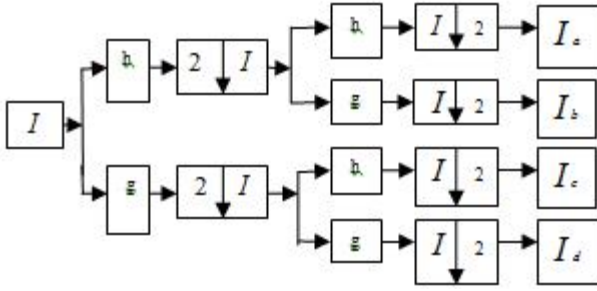
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Figure 1: Schematic of one-level 2-D Discrete Wavelet decomposition

There, a DWT with K decomposition levels will have M=3*K+1 such frequency bands. Figure 2 shows the 2-D structures of the wavelet transform with two decomposition levels. It should be noted that for a transform with K levels of decomposition, there is always only one low frequency band, the rest of bands are high frequency bands in a given decomposition level [9-11].
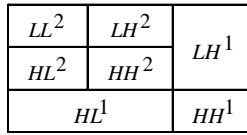
LL^2	LH^2	LH^1
HL^2	HH^2	
HL^1		HH^1

Figure 2: DWT structure with labelled sub bands

III. PROPOSED METHOD

The PET image shows the brain function and has a low spatial resolution; the MRI image shows the brain tissue anatomy and contains no functional information. Here, a new approach is proposed to fuse the medical images by combining Even degree method & Cross correlation process.

The entire procedure is as follows and it is shown in Fig. 3.

Step 1: Read the two source images A and B to be fused.

Step 2: Perform wavelet decomposition on the input Images. Then the low frequency (LL) and high frequency (LH, HL, HH) coefficients are extracted.

Step 3: Low Frequency fusion technique:

The low frequency coefficients are fused based on even degree method. The even degree of an image is defined as follows.

$$J_{LL} = \frac{1}{M \times N} \sum_{(x,y) \in LL} w(m) \times \frac{LL(x,y) - m}{m} \quad (1)$$

Where M, N are sized of LL, m is the mean value of LL, LL(x, y) denotes the coefficient value on (x, y) location and W(m) denotes a weight factor and is given by

$$w(m) = \left(\frac{1}{m}\right) \quad (2)$$

Then, the corresponding even degrees are compared to obtain the fused sub bands:

$$LL_f = \begin{cases} LL_A(i,j) & if : J_{LLA} >= J_{LLB} + TH \\ LL_B(i,j) & if : J_{LLA} < J_{LLB} + TH \\ \left[\dfrac{LL_A + LL_B}{2}\right] & others \end{cases} \quad (3)$$

Step 4: High frequency fusion technique:

The cross-correlation Coefficient (CC) between the decomposed MRI and the PET intensity image. The value of the coefficient varies from -1 to 1, with a value close to 1 indicating a strong similarity between two images, where as a value of -1 represents images not only with dissimilarity but also signifies that there is a strong inverse relationship between these two images. Then the high frequency coefficients are fused based on cross correlation coefficient method. For a given two M * N pixel images, the CC is given by [12] as follows:

$$corr(A/B) = \frac{\sum\limits_{i=1}^{M}\sum\limits_{j=1}^{N}\left(A_{i,j} - \overline{A}\right)\left(B_{i,j} - \overline{B}\right)}{\sqrt{\sum\limits_{i=1}^{M}\sum\limits_{j=1}^{N}\left(A_{i,j} - \overline{A}\right)^2 \sum\limits_{i=1}^{M}\sum\limits_{j=1}^{N}\left(B_{i,j} - \overline{B}\right)^2}} \quad (4)$$

$$LH_f = \begin{cases} LH_A(i,j) & if : CORR == 1 \\ LH_B(i,j) & otherwise \end{cases} \quad (5)$$

Apply the same technique for HL_f & HH_f also.

Step 5: Apply inverse DWT on fused LL_f, LH_f, HL_f & HH_f Coefficients to obtain fused intensity image.

Step 6: Finally the new intensity coordinate of image is transformed into RGB coordinates with original Hue & Saturation coordinates to obtain fused image.

IV. EXPERIMENTAL RESULTS

The test data consist of color PET and high resolution MRI images. The spatial resolution of MRI and PET images are 256×256 and 128×128 pixels. The color PET images were registered to the corresponding MRI images. All images have been downloading from the Harvard university site (http://www.med.harvard.edu/AANLIB/home.html). The original images and fusion results are displayed in Figure 4.

A. Peak signal to noise ratio

It is expressed in dB. Its value will be high when the fused and reference images are similar. Higher value implies better fusion.
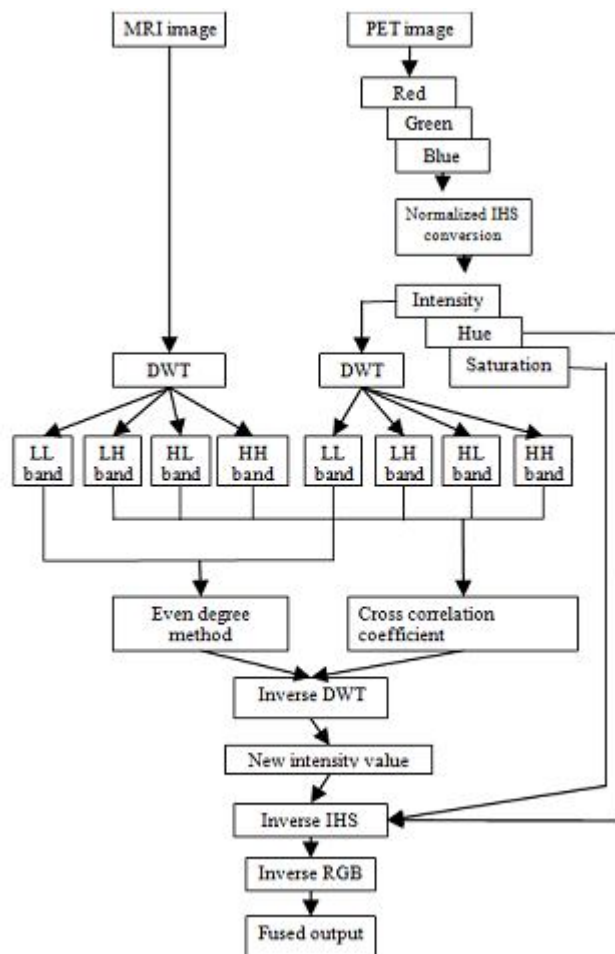
Figure 3: Block diagram of proposed method

Figure 4: New Mild Alzheimer's disease MRI and FDG-PET images (a) and (b) respectively (c) ground tooth image (d) IHS & PCA [4] (e) PCA (f) Brovey (g) DWT & SF [13] (h)Stationary Wavelet Transform, (i) DWT & PCA (j) DWT & PCA with Spatial Frequency[14] (k) the proposed method

$$PSNR(dB) = 10 * \log 10 \left[\frac{(255)^2}{\frac{1}{M \times N} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} (f(m,n) - g(m,n))^2} \right] \qquad (6)$$

B. Root mean squre error

The RMSE for the reference image R and fused image F (both of size $M \times N$) are defined as follows.

$$RMSE = \sqrt{\frac{1}{M \times N} \sum_{m=1}^{M} \sum_{n=1}^{N} [R(m,n) - F(m,n)]^2} \qquad (7)$$

Where $R(m,n)$ and $F(m,n)$ are the pixel value at position (m,n) of R and F, respectively. Smaller the values mean the better image quality.

The results from proposed method appear the best among all the results qualitatively and quantitatively. In this paper PSNR and RMSE are used to evaluate the effectiveness of the proposed method and graphically shown in Figure 5. It has been applied in many areas including, information fusion, and image registration, and comparing result is shown in Table I.
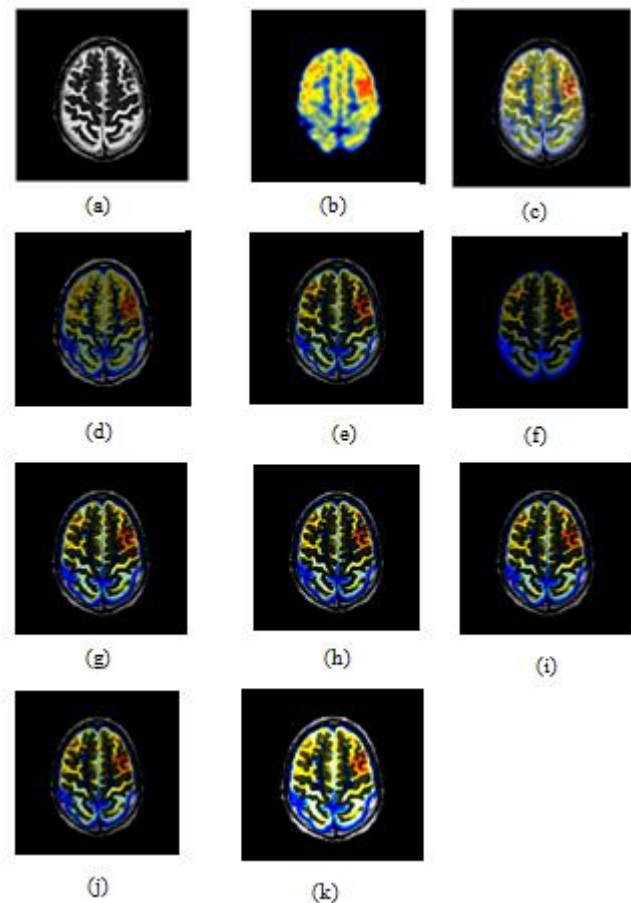
TABLE I. THE FUSION METHODS PERFORMANCE MEASURES

Fusion method	PSNR	RMSE
IHS & PCA [4]	46.4746	0.0260
PCA	56.7172	0.0692
Brovey method	58.1331	0.0500
DWT & SF(Spatial frequency) [13]	62.2149	0.0174
Stationary Wavelet Transform	62.5289	0.0182
DWT & PCA	62.7243	0.0174
DWT & PCA with SF [14]	63.3078	0.0152
Proposed method	**63.4051**	**0.0148**

V. CONCLUSION

In this work, a new approach multi modal image fusion scheme to incorporate the merits of cross correlation and even degree methods in to the image fusion technique. In the proposed algorithm, first, each of multimodal images are decomposed using DWT, then the coefficient are fused using
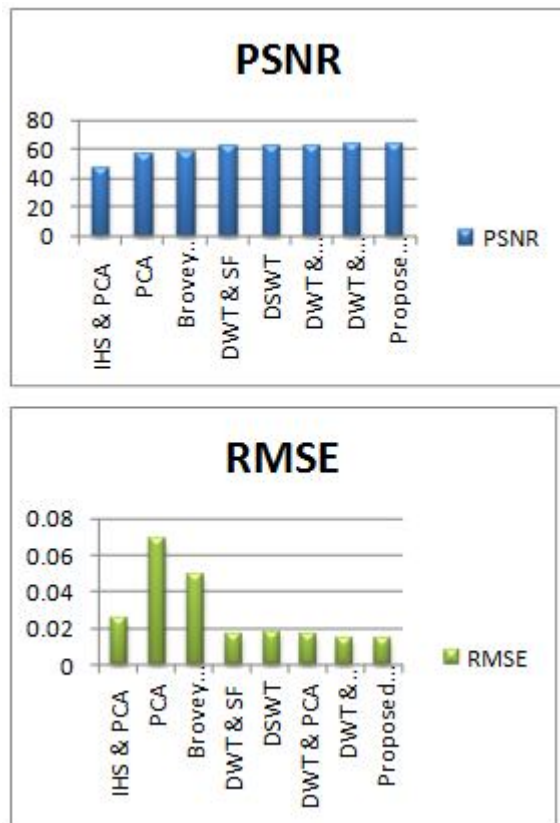
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Figure 5: Fusion performance of different methods

low & high band fusion rule and the fused coefficients are reconstructed by performing the inverse DWT. The proposed demonstrated the advantage over the classical fusion modal such as IHS & PCA, PCA, Brovey and multiscale transform methods such as DWT & SF(spatial frequency) [13], Stationary Wavelet transform, DWT & PCA, DWT & PCA with SF [14]. The superiority of the proposed algorithm is evaluated with the qualitative analytical measurement of PSNR and RMSE.

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M.Haribabu is currently working as Assistant Professor in ECE Department, QIS college of Engineering & Technology, Ongole. He has published 2 research paper in international conference.

Ch.Hima bindu is currently working as Associate Professor in ECE Department, QIS College of Engineering & Technology, ONGOLE, Andra Pradesh, India. She is working towards her Ph.D. at JNTUK, Kakinada, India. She received her M.Tech. from the same institute. She has ten years of experience of teaching undergraduate students and post graduate students. She has published 11 research papers in International journals and more than 9 research papers in National & International Conferences. Her research interests are in the areas of image Segmentation, image Feature Extraction and Signal Processing.

Dr.K.Satya Prasad is currently Professor in ECE Department, JNTUK, Kakinada, India. He received his Ph.D. from IIT, Madras. He has more than 32 years of experience in teaching and 25 years of R & D. He is an expert in Digital Signal Processing. He guided 10 PhD's and guiding 10 PhD scholars. He authored Electronic Devices and Circuits, Network Analysis and Signal & Systems text books. He held different positions in his carrier like Head of the Department, Vice Principal, Principal for JNTU Engg College and Director of Evaluation & presently the Rector of JNTUK. He published more than 100 technical papers in national and International journals and conferences. The area of interest includes Digital Signal Processing, Image Processing, and Communications etc.

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